FLORA AND FAUNA OF THE GALAPAGOS ISLANDS

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The author discusses the flora and fauna of the Galapagos Islands. Particular attention is given to finches, tortoises, cacti, and iguanas. It is concluded that Darwin was probably right regarding the origin of the unusual plants and animals he found on the Galapagos Islands, but wrong in his conclusions that his observations (and observations since) proved evolution.

Introduction

The Galapagos Islands lie on the equator in the eastern Pacific (when I visited the islands we crossed the equator three times in twenty-four hours). They are 600 miles from Ecuador, the country that exercises sovereignty over them, and a thousand miles from Panama. The closest islands are the forested Cocos, 600 miles northeast. West of the Galapagos there is no land for 3000 miles.

The largest of the islands is Albemarle, about 80 miles long. It has been suggested that originally this island consisted of five islands represented by its five mountains and that a subsequent lowering of the sea level united the five islands into a single large land mass.[1] The highest point is over 4000 feet above the sea.

Several of the other islands are between 10 and 20 miles across and rise to heights of between 2000 and 3000 feet. The larger islands include James, Chatham, Narborough, Indefatigable, and Charles. Fresh water is limited to Albemarle, Chatham (See Figure 1), Charles and James. There is brackish water available on Indefatigable: otherwise no water is available.

The rainy season lasts from mid-December to early March. During the rest of the year a southeast trade wind blows and normally no rain falls; yet a thick mist, the garua, covers the higher ground and makes agriculture possible at higher altitudes. Daytime temperatures are relatively cool for an equatorial region because the cold Humboldt current is nearby.

Figure 1. Charles Darwin statue, Chatham Island, at Wreck Bay. Author, Dr. Klotz, in foreground.

Island Habitats

In general the islands are arid and the landscape harsh-a great contrast from the tropical paradise some of the European settlers were persuaded they would find. Shorelines consist chiefly of low cliffs, black lava boulders, and a few dense mangrove swamps (Figure 2).

The most prominent plants of the lowlands are the tall tree cacti, the dildo trees, and the torch thistles. Ordinary bushes and trees including the thorny *Acacia* and the poisonous manzanilla are also present. In places, where the lava has flowed recently, much of the ground is bare; in some places the lava is so jagged that walking a hundred feet will cut a pair of shoes to shreds.

Inland and higher up there is humid forest with rich black soil, and tall trees covered with ferns, orchids, lichens, and mosses. In the very highest areas there is open country with grass, ferns, mosses, and occasional thickets.

Origin of Islands

One question that has been studied is that of the origin of the islands: whether they were formed-from volcanoes pushed up from the sea, or whether they were once connected by land to South America. In support of the idea of a land connection is the existence of raised beaches: on Albemarle, for instance, there are ancient sea cliffs and beach terraces several hundred feet above present sea level.[2] Some have suggested that there may have been a submergence of the

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intervening land or an elevation of the sea of as much as 2000 fathoms.

Yet it seems more likely that the islands were formed as a result of volcanic activity and that they were never connected to the South American mainland. On the American mainland opposite the Galapagos there are several hundred species of passerine and near-passerine birds. Habitats in the islands are similar to those which these birds occupy on the mainland, yet the descendants of only six passerine forms and one species of cuckoo live on the islands.

Similarly despite the rich variety of American mammals, reptiles, and amphibia, there are only two types of land mammals, five types of land reptiles and no amphibia on the islands. There are also great gaps in the flora.[3] If the islands had been connected to the mainland, it is hard to believe the flora and fauna would be so sparse.

Unusual Forms

These islands show a variety of unusual forms. These include 53 species of the land mollusc *Nesiotus;* two genera of iguanas, *Conolophus* and *Amblyrhyncus,* both represented by a single species; a giant tortoise, *Geochelone,* which exists in several forms which Darwin regarded as separate species; a lizard, *Tropidurus,* which exists in seven or eight different island forms; a gecko, *Phyllodactylus;* and a snake, *Dromicus.*[4] There is also a rice rat, *Nesoryxomys,* and a bat, *Lasiurus brachyotis.*

Domestic animals have been introduced by settlers: many of these are now feral. There are two species of ants, *Camponotus macilentus* and *C. planus;* these occur in a number of forms. There are four species of grasshopper: *Halmenus, Liparoscelis, Schistocerca,* and *Sphingonotus.* None of the insects seems to have developed into separate species.

One of the Galapagos plants, *Scalesia,* is supposed to have developed into separate species, six in number.[5] Other plants that are said to have developed particular Galapagos species are *Telanthera, Acalypha,* and *Euphorbia. Euphorbia viminea* is said to have produced eight different geographical forms. Especially interesting are the two cacti, *Cereus* and *Opuntia.* Both have developed tree-like forms with trunks and bark. There are a number of other plants such as the thorny *Acacias,* the poisonous *Hippomane mancinella, Bursera, Croton,* and *Maytenus.*[6]

The Finches

Probably the most famous of the Galapagos forms are the birds, and of these the finches have received most attention. It is believed that there are 14 different species belonging to four different genera.

Figure 2. Lava cliffs and rugged terrain of the Galapagos.

There are six species of ground finches belonging to the genus *Geospiza:* the large ground finch *(G. magnirostris),* the medium ground finch (G. *fortis),* the small ground finch *(G. fuliginosa),* the sharp beaked ground finch *(G. difficilis),* the cactus ground finch *(G. scandens),* and the large cactus ground finch *(G. conirostris).*

There are also six‘ species of tree finches: the vegetarian tree finch *(Camarhynchus crassirostris),* the large insectivorous tree finch *(C. psittacula),* the Charles Island large insectivorous tree finch *(C. pauper),* the small insectivorous tree finch, *(C. parvulus),* the woodpecker finch *(C. pallidus),* and the mangrove finch *(C. heliobates).*

The warbler finch *(Certhidea olivacea)* is the sole representative of its genus as is also the *Cocos* finch *(Pinaroloxias inornata),* which does not occur on the Galapagos proper.

Most of these species occur on a number of islands. The large ground finch, *G. magnirostris,* for instance, is reported from nine different islands; the woodpecker finch, *C. pallidus,* from five islands. The large insectivorous tree finch, *C. pauper,* however is known only from Charles island, and the cocos finch only from Cocos Island which is really not part of the Galapagos.[7]

The chief way in which these species differ is in their beaks. The large, medium, small and sharp-beaked ground finches eat seeds: also a variety of fruits, flowers, buds, young leaves, and caterpillars. Their beaks are heavy and finch-like.

The beak of the cactus ground finch is long and decurved, suggesting flower probing and nectar feeding: its stable food is the flowers of the prickly pear, *Opuntia.* It also feeds on the soft pulp of the *Opuntia* and on other types of food including the seeds that form the bulk of the food of the other ground finches. Thus it has not completely departed from the typical ground finch diet.

The vegetarian tree finch, *C. crassirostris,* has a short, thick somewhat decurved and slightly parrot-like beak, similar to that of other birds that feed primarily on leaves, buds, blossoms, and fruits. It rarely takes insects and has not been observed to take grain, but does eat some types of seeds.

The three insectivorous tree finches have beaks very similar in shape to that of the vegetarian tree finch, yet their diet consists of beetles and similar insects which they dig out of twigs, bark, and leaf clusters and also from the soft wood. Lack believes that this resemblance is due not to diet but because they are closely related by descent.[8]

The woodpecker finch, *C. pallidus,* has a stout, straight beak similar to those of the insectivorous tree finches but more elongated and modified in the direction of that of a woodpecker or nuthatch. It is more exclusively insectivorous than the insectivorous tree finches. Moreover it climbs up and down vertical trunks and branches.

The mangrove finch, *C. heliobates,* has a similar beak and feeds almost exclusively on insects, and the warbler finch, *Certhidea olivacea,* has a warbler-like beak. It searches leaves, twigs, and ground vegetation for insects and sometimes catches insects in the air.

The Cocos finch, *Pinaroloxias inornata,* has a slender beak similar to that of the warbler finch. It feeds predominantly on insects.[9]

How did these finch species originate? Darwin thought that they had come from a common stock and that because they were now separate species he had "proved" evolution.

The Origin of the Finches

There seems no reason to question their origin from a common ancestor. They show marked similarities to each other, but oddly enough they do not show close resemblance to any particular species of finch on the South or Central American mainland.[10] It is believed that the ancestral finch first became differentiated into various forms because of geographical isolation on different islands.

After a period of isolation, some had become so different that when they met on the same island they were already intersterile. Such new species must have tended to compete with each other when they met: both could survive only if they were better adapted to one part of the food supply or habitat which was then divided between them. The restricted habitat led to further specialization and greater divergence.[11]

Evolutionists have generally assumed the origin of all the finch species from a single gravid female, a single pair or at most a very small number reaching the islands together. Lammerts, however, suggests that many pairs of finches from Ecuador or even Central America happened to fly to the Galapagos and settle there? This would provide a substantial amount of original variation.

Lack points out that birds are capable of active dispersal from one island to another and that the finches could often reach an island inhabited by a different form in an hour's continuous flight. He raises the question of how bird populations could remain isolated from each other.[13]

We know that birds are capable of long sustained flights in migration. The Galapagos are situated in the Sea of Calms, an area in which storms are infrequent, and it seems quite plausible to assume more than one invasion of the islands by finches. There is of course the problem of why so few South American bird species are represented, but there is no reason to insist on a single finch invasion. On the other hand, there is no serious problem if a single invasion is assumed.

Are they separate species? A number of questions arise when we study these finches. The first of these is whether these species are really intersterile and consequently "good" species. The evidence seems to point in this direction. Studies on captive finches indicate the several species have bred successfully with others of their own group but not with members of different species.[14]

More significant are the field observations which have been made. These have necessarily been somewhat limited, but they have failed to indicate any instances of hybridization even though this has been suggested by some writers. At first it may seem that some of the intermediate forms reported from the various islands are of hybrid origin, but Lack believes they represent special adaptive modifications.[15] He recognizes that there may be a few hybrids[16] but believes these are the exception rather than the rule. There is no reason to doubt that new species arise[17] and there is no reason to question the conclusions of Darwin and those who followed him that new species of finches have arisen on the Galapagos Islands.

Lammerts in a study of the most complete collection of skins, that of the California Academy of Science, suggests that these are all one species broken up into various island forms as a result of chance rearrangement of the original vari-

Figure 3. Cactus ground finch with dark plumage, *Geospiza conirostris conirostris.*

ability potential. He does however believe that *Certhidea,* the warbler finch, is distinctive.[18] It is interesting that he expresses the opinion that the four species of *Certhidea* of the California collection are actually one species. an opinion with which Lack apparently concurs. Lammerts' careful measurements and his comparison of the Galapagos finch situation with that of the song sparrow, *Melospiza melodia,* deserve serious consideration and raise some interesting questions.

However, assuming: there are 14 "good" species, we must recognize that the problem of evolution is much wider than the origin of species. These birds are all still finches, and there is no evidence of change of the magnitude which macroevolution would require.

Problems of Evolutionary Theory

Moreover there are some interesting observations made on the Galapagos finches which do not fit with some of the more generally accepted principles of evolutionary theory. According to Gloger's rule, birds of more humid environments should have darker plumage than those of drier climates. Most of the tree finches, *Camarhynchus,* breed in the humid forest and the ground finches of the genus *Geospiza* breed in the arid lowlands, but the tree finches have paler plumage than the ground finches. The ground finch with the darkest female plumage is *G. conirostris conirostis* (Figure 3) which is confined to the particularly arid lowlands of Hood.[19]

It is also interesting that the Galapagos finches have extremely few natural enemies.[20] Under these circumstances we might expect them to develop conspicuous coloration: there should be no limit on the development of bright colors in keeping with sexual selection theories. It might be argued that the original drabness prevented the development of conspicuous coloration; yet what is happening is that the distinctive male plumage, which is present, is being lost. Lack reports that many males breed in the plumage of the juvenile pattern.[21]

While it is believed that marked beak differences between island forms of the same species are adaptive, many of the smaller differences in beak or wing length are extremely difficult to correlate with adaptation to the environment. Lack has a long list of what he calls "pointless variations."[22] He believes it is difficult to demonstrate that these are non-adaptive, but he expresses the opinion that many of these are genuinely unrelated to environmental differences.

It is also interesting to note that there is a great deal of individual variation in the beaks of Galapagos finches. This is significant because the significant species differences are in the structure of the beaks. In several cases one island form was earlier thought to consist of two separate species because of this variation. In some cases the beak is so unusual that the species cannot be determined.[23]

Mockingbirds

Darwin was more impressed by the different forms of mockingbirds and tortoises. In his private diary of the first voyage the finches are not even mentioned and in the first published edition of the *JOURNAL* they received only brief notice without comment.[21]

The mockingbirds have obvious affinities with the mainland genus, *Mimus,* but it is different enough to be placed in a separate genus, or subgenus, *Nesomimus.* No island has more than one form, but it is believed there are at least three and possibly four species involved.

The Galapagos mockingbird (Figure 4) has a much broader feeding niche than the mainland species, perhaps even wider than all the mainland species combined.[25] Mockingbirds are famous for the beauty and complexity of their singing, but the Galapagos mockingbird has a simple, dull, and quiet song.[26] The loss of this mockingbird characteristic is as much a problem for evolution theory as is the loss of male plumage on the finches.

The Tortoises

The other form which impressed Darwin was the tortoise (Figure 5). It is generally agreed that there is only one species, *Geochelone elephantopus,* with fifteen subspecies. Ten of these occur on 10 different islands, and five are found

Figure 4. Mockingbird from Champion Island.

Figure 5. Galapagos tortoise, *Geochelone elephantopus.*

on Albemarle. These are believed to have developed on separate islands which became united into a single mass by the lowering of the sea level or by the elevation of the land mass.

The giant tortoises were discovered in the early 16th century. Later they were collected by buccaneers who used them as food. Still later whaling ships used them in the same way. One author reports a total of over 15,000 tortoises recorded in the logs of some 105 whaling ships between 1811 and 1844. During this period there were over 700 ships in the American whaling fleet alone without counting the whaling fleets of other nations, seal hunters, and merchantmen.[27]

The tortoises provided an ideal source of meat on board ship because they could live for months without food and water. There are records of their storage in the hold of a ship for seven months and reports of their having remained alive for as much as 18 months. It is believed that over 100,000 tortoises were taken.[28]

In addition to the large number of reptiles taken, the sex ratio was upset. Normally the tortoises live at higher altitudes; only the females come down to the coast to lay their eggs. Most of the tortoises taken were females on their way to or from the beaches.

Still later the settlers hunted the tortoises for their fat. Feral goats, cattle, and burros competed for available food; and feral cats, dogs, pigs, and rats were a major threat to the young tortoises. Very possibly some of the tortoise varieties have not bred successfully in the 20th century. It is believed that today only on Indefatigable and Albemarle are there sufficient numbers of tortoises to constitute a viable population.

It seems reasonable to believe that the tortoise came from South America, since fossil tortoises are found there. It is reported that the tortoise can float and survive for long periods in sea water. Some investigators have suggested that the ancestor that made the trip was smaller than the Galapagos tortoise at present: it is easier to imagine a small tortoise making the trip than a large one. Possibly the present large size developed after they reached the islands; however, there are fossils of large tortoises in South America.[29]

It is believed that when the first tortoises arrived they found an environment that was both favorable and unfavorable. There were no representatives of either the dog or cat family, animals which regularly eat a great many young tortoises. However, the food supply was limited, at least in variety. It is suggested that they first turned to the tomatoes they found growing there. Supposedly because they had a monopoly of this food source, they developed their large size.

The Cacti

Two cacti genera are quite common: *Opuntia* (Figure 6) and *Cereus.* In addition a single species of *Brachycereus* is known as well as three species of *Jasminocereus.*[30] *Optuntia* and *Cereus* seem to have reached the islands many years ago: no doubt they came on natural rafts together with other plants and animals.

Such natural rafts have been observed over 100 miles off the mouths of large tropical rivers,[31] and one was observed a distance of 1000 miles at sea. In particular enormous rafts of sudd have been observed moving seaward from the mouth of the Guayas River. The Humboldt current flows past the Salinas peninsula where the Guayas empties into the Pacific to the Galapagos. Cacti are known to be resistant to sea water.

It is believed that the seven *Opuntia* species listed are derived from at least two ancestors. *Brachycereus* is believed to have arrived in relatively recent years. It is quite similar to *Armatocereus* of Ecuador. It occupies the five northern islands.

Jasminocereus is less like its nearest Ecuadorian relative, *Monvillea.* It is believed to consist of three species and occupies at least five major islands. There are a number of islands from which it is absent, yet it seems to have ready access to these islands, and its absence from these islands is puzzling.

There are two principle forms of *Opuntia:* one group shows the prostrate or sprawling habit, and the other, *O. galapageia,* the erect aborescent habit (Figure 7). This second group has attracted special attention because of the extraordinary size of the erect plants and definite trunk development. Many plants reach a height of 15 feet, and tree cacti of 30 or more feet in height are not unknown.

In only a few other places have the opuntias developed this aborescent habit, and it has been suggested that this is due to the feeding of the giant tortoises. Moreover where there are no tortoises the opuntias have the prostrate or sprawling habit.

On lava shores the cacti provide the only food and drink for an herbivorous reptile. It is suggested that the ancestral tortoises consumed many of the succulent, decumbent ancestral opuntias. The rough lava landscape did provide some places that were inaccessible to the tortoises, and here the opuntias survived. Subsequently the opuntias are believed to have adapted to the grazing of large numbers of tortoises while providing these tortoises with large quantities of food and drink.

The opuntias have large seeds which provide for large and rapidly growing seedlings. These develop heavy spinations very quickly, and the branching consists of a succession of pads, each from the apex of the preceeding one: this provides for rapid growth in height during a few growing seasons.

Tortoises do not graze on the young, weak-spined, growing stems, for during this growing season food is relatively abundant. Grazing occurs during the dry season; by this time heavy spinescence has developed. The erect growth

Figure 6. Cacti in bloom on Tower Island.

and spiny armament discourages herbivores. Later when growth in diameter leaves gaps between the spines a thick papery bark develops which discourages feeding.

While the cacti are protected, they nevertheless provide food for the tortoises. Spination is progressively reduced as height increases and the upper branches usually have only soft, bristle-like spines. At the beginning of the rainy season the shriveled pads of the preceding year fill with water and this additional weight frequently breaks the pads or even whole branches off, causing them to fall to the ground. Here they serve as food for the tortoises during the dry season. The fruits, too, supply food for the tortoises: they fall to the ground and are quite attractive to the tortoises who apparently relish them.[32]

Evolutionary Implications

Now what has all this to do with evolution? Darwin and his successors felt that the variations in the island forms of the tortoises was evidence that evolution had occurred and was occurring, and they felt that the arborescent habit of the cacti was an evolutionary adaptation to tortoise feeding.

It is interesting to note though that the tortoises (which certainly show marked and interesting morphological differences from island to island) are nevertheless classified as a single spe-

Figure 7. Cactus forest on Indefatigable showing tree forms, *Opuntia galapageia.*

ties. While a great deal of variation has occurred there is no evidence that a new species has arisen (and even this would not be evidence for macro-evolution). There is certainly no reason why tortoise varieties should not have arisen on the different islands.

It is also interesting to note that while some believe large size has developed in the tortoises since they came to the Galapagos, there is fossil evidence of large tortoises on the South American mainland from which it is generally agreed the Galapagos tortoise population is derived.

How carefully the cacti studies have been conducted is not clear from the literature. It is not clear whether *Opuntia, Cereus* and *Jasmino-*cereus are divided into species on the basis of a variety of studies, or whether the division is made merely on the basis of morphology. The unusual aspect about the Galagapos cacti is their aborescent form; and it is quite plausible that this is an adaptation to tortoise feeding.

What is especially interesting in this connection is the report of Dawson that on Jervis where the tortoises are extinct or close to extinction the arborescent habit is not being strictly maintained. This is one of the islands that has not seen the introduction of goats which also feed on the cacti, and Dawson reports there is a great deal of regrowth from the fallen pads. These, however, produce a low, shrubby form, though growth from seeds produces a distinctly erect form.[33]

This same author reports a similar situation from the Daphne Major Islet where one of the opuntias shows degeneration from the arborescent form in the absence of tortoise grazing. Again plants developing from seeds tend to be erect while those developing from pads grow into a low form. On this islet low shrubby habit seems to dominate which would indicate that in the absence of tortoise grazing it is better able to survive. Thus the arborescent habit may actually be an undesirable form which is able to survive only when the shrubby form is at a marked disadvantage from tortoise or goat grazing.

Iguanas

Another unusual Galapagos form is the iguana. There are two species known, *Conolophus,* the land iguana (Figure 8), and *Amblyrhynchus cristatus,* the marine iguana (Figure 9). Both show some differentiation from island to island. It is believed that the two species developed from a single original colonist.[31] Some Crea-

tionists believe it is more likely that both species arrived as colonists on the island. The land iguana feeds primarily on cacti, and the marine iguana feeds primarily on green algae.

It is the marine iguana that has attracted special attention. This lizard dives into the water and grazes on the green algae which grow on the rocks. It is the only known iguana with this sort of diet. The sea is cool; yet it suns itself on hot rocks exposed to the intense equatorial sun. After a trip into the water to feed, these iguana apparently must spend a given period of time on the rocks to dry out and to warm up before returning to the sea. (Another unusual characteristic is a salt gland in the head in which it apparently concentrates salt which it expels in a small pellet through the nares.)

It has been suggested that the feeding habits of the marine iguanas together with their willingness to enter the sea is the consequence of evolutionary development, that they came to the islands and found the only available food the cacti and other land plants. These were insufficient to support the growing iguana populations; therefore, some of them then turned to the sea which they have exploited so effectively that, whereas the land iguana is threatened with extinction, the marine iguana is not.

Figure 8. Land iguana, *Conolophus.*

Are Darwin's Conclusions Supported?

In the case of these iguanas, as with all the other Galapagos forms (and there are a number of other unusual forms which cannot be mentioned in this brief review), the question is the amount of change possible and whether changes of a considerable magnitude are indeed evidence for macroevolution.

There is no reason to doubt that the forms God created were created with considerable potential for variability, that they could adapt to a variety of habitats, that these adaptations may be expected to bring about marked morphological, physiological, and behavioral changes.

There seems little reason to question the accepted explanation for the origin of these unusual plant and animal forms: most of them seem to have come from the South American mainland.

Nor does there seem reason to question the suggestion that they have undergone marked change in the generally harsh, inhospitable environment of the Galapagos: that there are any plants and animals on the islands is a testimony to God's wisdom in providing adaptive potential in the forms He created.

A large part of Darwin's problem came from his acceptance of the fixity of species concept. He believed that Scripture taught the creation of forms with very limited potential for change and that certainly the species barrier was insurmountable, for he identified the "kinds" of Genesis with the species he knew.

Thus Darwin was both right and wrong: generally right in his explanation of the origin of the unusual plant and animal forms he observed on the Galapagos, but wrong in his conclusion that when he demonstrated change and even the origin of new species he had proven macroevolution.

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